Model Evaluation and Uncertainties: Study case for a Chinese haze event measured during KORUS-AQ

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NASA DC-8
LaRC King Air
Hanseo King Air

Korean and US Air Quality Model Forecasts
(May-June 2016)
WRF-Chem forecasting system for KORUS-AQ

- WRF-Chem with MOSAIC aerosols (4 size bins) and a Reduced Hydrocarbon chemistry (Pfister et al. JGR 2014), including simplified SOA formation (Hodzic and Jimenez, GMD 2011)
- GFS and MACC meteorological and chemical boundary conditions
- KORUS-AQ anthro (Jung-Hun Woo) and QFED fire emissions
- AOD data assimilation using GSI (Saide et al., ACP 2013). MODIS and GOCI data were assimilated simultaneously every three hours (Saide et al., GRL 2014).
- Four days of forecasts were available for the outer domain, 2 days for the inner domain

Saide et al., ACP 2020
Evaluation against AERONET and surface PM

• AOD well captured over South Korea
• Over-predicted surface PM, especially PM2.5 often by a factor of 2 or larger

Saide et al., ACP 2020
DIAL-HSRL vs WRF-Chem May 24th (Extinction [1/km])

Saide et al., ACP 2020
Some definitions

• Mass Extinction efficiency (MEE) and Volume Extinction efficiency (VEE):

\[
MEE = \frac{\text{Dry extinction}}{\text{Mass concentration}} \quad \quad \quad VEE = \frac{\text{Dry extinction}}{\text{Volume concentration}}
\]

Mass concentration: AMS (<1 \, \mu m), Volume concentration: size distributions (<5 \, \mu m), Extinction: nephelometer (<5 \, \mu m)

• Scattering enhancement factor due to aerosol hygroscopic growth: \( f(RH) \)

\[
f(RH) = \frac{\text{Scattering at 80% RH}}{\text{Dry scattering (20% RH)}}
\]

Saide et al., ACP 2020
Observed size distribution

- Forecast used 4 bins, more advanced configurations use 8
- Large heterogeneity within bins before aggregating

Saide et al., ACP 2020
Closure study: MEE

Drive optical properties code with observed quantities (size distr. and chemical composition)

Updated refractive index based on literature: Amonium-nitrate (1.5 to 1.55), Organic aerosol (1.45 to 1.55)
Closure study: f(RH)

Drive optical properties code with observed quantities (size distr. and chemical composition)

Updated hygroscopicity parameter based on literature: Ammonium-nitrate (0.5 to 0.67), Ammonium-sulfate (0.5 to 0.61) and organic aerosol and dust (0 to 0.14)
How is the model resolving the size distribution?

MADE2 uses narrower standard deviation (GSD) of accumulation mode aerosol
How is the model resolving aerosol composition?

- Low concentrations of secondary aerosols
- Overpredict primary (less hygroscopic) fractions

Saide et al., ACP 2020
Testing WRF-Chem configurations

As in closure studies, agreement with observations can be obtained by refining bins, updating refractive indexes, and updated hygroscopicity.

<table>
<thead>
<tr>
<th>Name</th>
<th>Aerosol Scheme</th>
<th>Size bins used for OP</th>
<th>GSD of the modes</th>
<th>Refractive index</th>
<th>Hygroscopicity</th>
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<tr>
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Volume extinction efficiency [m$^2$m$^{-3}$]

(f(RH))

Saide et al., ACP 2020
Conclusions

• Multiple sources of model deficiency related to the calculation of optical properties explain discrepancies between AOD and PM2.5

• How to fix it?
  • Increase size bins resolution
  • Increase refractive indexes and hygroscopicity parameters
  • Improve secondary aerosol formation pathways

• Implications to as air quality forecasts, health-effect assessments, climate projections, solar-power forecasts

Thanks! Questions or comments?
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Supplemental slides
Example of AOD assimilation impact during KORUS-AQ (May 24\textsuperscript{th} flight, Chinese haze over Yellow sea)

Saide et al., ACP 2020
Testing WRF-Chem configurations

Inconsistencies between MEE and VEE due to:

- Size distribution
- Speciation
- Organic aerosol density

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![Mass extinction efficiency](image1)

![Volume extinction efficiency](image2)